OPHTHALMIC LENS WITH DIFFRACTIVE POWER

RELATED APPLICATIONS

This application is a continuation-in-part of my earlier application Ser. No. 368,362 filed on Apr. 14, 1982 entitled ARTIFICIAL EYE LENSES.

This invention concerns improvements in or relating to ophthalmic lenses, including in particular contact lenses and spectacle lenses.

The human eye is known to exhibit longitudinal chromatic aberration so that objects at the same distance but of different colours cannot all be sharply focussed at the same time. Thus, to effect simultaneous sharp focussing orange and red objects need to be placed farther away than a green object while blue and violet objects have to be nearer the eye than the green object. The extent of the effect is about one dioptre and there is evidence to suggest that the eye/brain system makes use of this to avoid refocussing, concentrating on the blue components of objects that are close and on the red components for distant vision.

According to the present invention there is provided an ophthalmic lens having negative diffractive power which introduces positive longitudinal chromatic aberration. Such introduced positive longitudinal chromatic aberration adds to the natural longitudinal chromatic aberration of the eye and hence increases the range of the chromatic effect. This can enable the eye/brain system to perform a wider variety of tasks without need to adjust the eye focus (accommodate) by concentrating on the appropriate colour component at the different respective distances. If the extent of positive longitudinal chromatic aberration required to be introduced by the ophthalmic lens is D dioptres, then the diffractive power of the lens is preferably about $-3.4D$ dioptres; for example if the required extent of the introduced aberration is $+1$ dioptre (to give, with the eye's natural extent of $+1$ dioptre, a total range of $+2$ dioptres), then the diffractive power of the lens may be about -3.4 dioptres.

The ophthalmic lens preferably has refractive power so that the overall, or residual, power of the lens is determined by the algebraic sum of the diffractive and refractive powers. If desired, the refractive power may be positive and of a magnitude such as to balance, or cancel, the diffractive power so that the overall or residual power is substantially zero. For example, where the lens has a diffractive power of about -3.4 dioptres it may have a refractive power of about $+3.4$ dioptres so that there is no substantial residual power. Alternatively, however, the relative values of the diffractive and refractive powers may be such as to provide the lens with an overall or residual power, for example to give a required corrective power for the particular eye with which the ophthalmic lens is to be used. Thus, the refractive power may be positive and of greater magnitude than the diffractive power to give a positive residual power, or may be positive but of smaller magnitude than the diffractive power to give a negative residual power, or may be negative to give a greater negative overall power.

The refractive power is preferably provided by faces which are curved as viewed in axial-section, and which may be of spherical curvature.

The diffractive power is preferably provided by a transmission hologram. The hologram may be optically generated in a surface layer of the lens or within the bulk material of the lens, or may be mechanically generated as a surface relief hologram on the lens or within the lens. The diffractive power may be provided over the full visually used area of the lens, or may be provided over part only of that area. The lens may be a contact lens which may have the diffractive power over its full visually used area. Alternatively, the lens may be a spectacle lens which may have the diffractive power over part only of the visually used area, e.g. over a part corresponding to the near or reading portion of a bifocal or progressive spectacle lens. As a further possibility the lens could be an implant lens in which case the diffractive power is preferably provided over the full visually used area of the lens.

The efficiency of diffraction is preferably more than 50% at all wavelengths across the visible spectrum and the maximum efficiency is preferably more than 70%. The difference between the maximum and minimum efficiencies across the visible spectrum is preferably less than 20%, e.g. if the maximum efficiency is nearly 100% then the minimum efficiency is preferably more than 80%.

In order that the invention may be better understood, reference will now be made to the accompanying drawing in which:

FIG. 1 is a schematic (and not to scale) representation of the chromatic viewing properties of a normal human eye,

FIG. 2 is a schematic (and not to scale) representation similar to FIG. 1 but with an ophthalmic lens in accordance with the invention associated with the eye.

Referring to FIG. 1, the normal human eye E has a cornea C and natural lens L by which light is focussed at F to form an image on the retina. Objects at different distances are viewed by adjusting the shape of the natural lens L (through the action of the eye muscles) so as to alter its focal length to achieve focussing at the point F of light from the respective object distance. This property of the eye is commonly known as "accommodation". However, the eye exhibits longitudinal chromatic aberration, which means that with the eye lens L at any one accommodation setting different colours from the same distance are not all focussed at the same point. This arises because the media of the eye have refractive indices which are slightly greater at the blue end of the spectrum than at the red end. Conversely, therefore, at any one accommodation setting, the eye can sharply focus on to the retina the image of a blue object at one distance and the image of a red object at a greater distance. This is illustrated in FIG. 1 which shows a blue object B nearer the eye and a red object R further from the eye, from both of which light is sharply focussed on the retina at F with the lens L at the same accommodation setting. Between the blue and red objects there is shown a green object G (wavelength 555 nm) whose image is also sharply focussed on to the retina at F at that particular accommodation setting. It will be understood that the distance variation is continuous through the visible spectrum and that blue, green and red objects are given as illustrative.

As a particular example of the variation at a specific accommodation setting, if in FIG. 1 the green object G is at a distance of one meter from the eye E and the eye lens L is in a state of accommodation such that (in conjunction with the action of the cornea C) an image of the green object G is sharply focussed on the retina at F,